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ABSTRACT

Defining schemas as higher order cognitive structures that serve a crucial role in providing an account of how old knowledge interacts with new in perception, language, thought, and memory, this paper offers an analytic account of the nature and functions of schemas in psychological theory and organizes some of the experimental evidence dealing with the operation of schemas in memory. The paper is organized into six sections, the first of which provides a detailed examination of the schema concept as formulated by F. C. Bartlett in 1932. The second section relates Bartlett's theory to the larger issue of the conflict in psychological theory between ideas from British Empiricism and ideas from Continental philosophy. The third section briefly outlines some of the basic theoretical assumptions of information processing psychology to serve as a background for an analysis of schema theory, and the fourth examines modern schema theory, and contrasts it with Bartlett's theory and with the information processing approach. The fifth section discusses the nature of schemas, specifically mentioning ontological assumptions, modularity, ecological validity, and phenomenal experience, while the final section develops a framework for analyzing the functions of schemas in the memory process, and then examines a number of recent experiments in terms of this framework. A 16-page bibliography is included. (FL)

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Technical Report No. 325

THE NATURE AND FUNCTIONS OF SCHEMAS

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September 1984

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The Nature and Functions of Schemas

Schema theory is one of the most intellectually exciting areas of current cognitive psychology. There has been a very rapid growth of ideas and data on this topic so that it is difficult to understand what has been accomplished. In this paper we attempt to give an analytic account of the nature and functions of schemas in psychological theory and to organize some of the experimental evidence dealing with the operation of schemas in human memory. We will restrict ourselves to laboratory studies and theories from cognitive psychology and artificial intelligence and will not cover the schema literature from social psychology.

Much of this paper is devoted to attempting to understand what schemas are. In brief, they are higher-order cognitive structures that have been hypothesized to underlie many aspects of human knowledge and skill. They serve a crucial role in providing an account of how old knowledge interacts with new knowledge in perception, language, thought, and memory.

This paper is organized into six sections. The first section is devoted to a detailed examination of the schema concept as formulated by Bartlett. The second section relates Bartlett's theory to the larger issue of the conflict in psychological theory between ideas from British Empiricism and ideas from Continental philosophy. The third section briefly

outlines some of the basic theoretical assumptions of information processing psychology in order to serve as a background for our analysis of schema theory. In the fourth section we examine modern schema theory (e.g., Minsky, 1975; Rumelhart & Ortony, 1977; Rumelhart, 1980, reprinted in this volume) and contrast these theories with Bartlett's theory and with the information processing approach. In the fifth section we sketch out our own position. In the final section we develop a framework for analyzing the functions of schemas in the human memory process and then examine a number of recent experiments in terms of this framework.

Bartlett's Schema Theory

The schema theory Bartlett developed in his book Remembering (1932), has been the inspiration for most modern schema theories. Bartlett's work is a particularly powerful presentation of schema theory and on some issues his theory is worked out in more depth than current schema theories, so his work merits careful consideration. In this section we will analyze Bartlett's basic assumptions and lay out the conceptual core of his theory.

Bartlett's Definition of Schemas

Bartlett (1932) defined a schema as "an active organization of past reactions, or of past experiences, which must always be supposed to be operating in any well-adapted organic response" (p. 201). Bartlett's book consists of an elaboration of his schema theory and an application of it to data he had gathered

much earlier on memory for figures, pictures, and stories (e.g., Bartlett, 1916, 1920, 1921).

First we would like to know what kind of construct schemas were for Bartlett. In the terms of modern philosophy of science (cf. Suppe, 1977), was Bartlett an instrumentalist (schemas are just constructs used to organize the data) or was he a realist (schemas exist and the schema theory attempts to describes them)? It is clear from Bartlett's text that he was a realist with respect to his schema theory. Given that he is a realist what kind of entities does he think schemas are? It appears he assumes that they are unconscious mental processes. In a discussion of the neurologist Head's schema theory Bartlett stated that "schemata are active, without any awareness at all" (1932, p. 200) and even more clearly in his autobiography he stated that schemas have the same status as images and ideas but that they are not available to introspection (1936, p. 47).

The hypothesis that schemas are complex unconscious knowledge structures is one of Bartlett's major contributions. In his book Bartlett generously gave Head credit for developing the schema hypothesis. However, on this issue, as on many others, Bartlett's theory is very different. Head gave only a sketchy account of his approach, but it seems likely that he considered schemas to be physiological entities. Thus, he stated, "schemata lie for ever outside consciousness; they are physiological processes with no direct psychical equivalent"

(Head, 1918, p. 158). Many psychologists and philosophers have found the concept of an unconscious mental process hard to accept. When the Wurzberg psychologists postulated such entities they were attacked by the introspective psychologists of the time, who belived that the data of psychology were restricted to conscious phenomena (see Humphrey, 1951). They were also attacked by behaviorists, who thought that the data of psychology were restricted to observations of overt behavior (Watson, 1913). However, in recent years a number of philosophers have made powerful arguments for the acceptance of unconscious mental processes as proper objects of scientific study (e.g., Fodor, 1968; Putnam, 1973) and these processes form the core of modern information processing psychology.

Properties of Schemas

Having established that Bartlett took schemas to be unconscious mental structures, we now examine their characteristics. In Bartlett's (1932) abstract definition of schemas he consistently described them as "organized," but gave little further specification. He did state that the term "pattern" would not be quite accurate, since it implies more detail than he intended. However, in the analysis of the various memory experiments reported in his book he gave a number of examples that help clarify his use of the term "organized." He probably intended the term to cover the organization involved in such things as: symmetrical visual figures (p. 24); rules (p.

52); the plan of a prose passage (p. 83--he gives the structure of a "cumulative story" as an example, cf. Rumelhart, 1975); and literary conventions (p. 140--he gives ending with a moral as an example, cf. Brewer, in press). If this is a correct reading of Bartlett, then it is clear that the term "organized" covers a very wide range of cognitive structures.

Another fundamental aspect of schemas in Bartlett's theory is that they are composed of old knowledge. Thus, he stated that they are "masses of organized past experiences" (1932, pp. 197-198). However, there are a wide variety of ways in which old knowledge could be represented and Bartlett had a specific hypothesis about the form of representation in schemas. In particular, Bartlett wanted to develop an alternative to the standard British Empiricist view that old knowledge was represented in the form of a collection of specific mental images (e.g., Hobbs, Berkeley, James Mill). Head and Holmes (1911, p. 186) had initially developed schema theory in neurology as an alternative to the image view as applied to body posture and movement. This was one important component of Head's theory that Bartlett wanted to retain. However, he wanted to apply it to all the higher mental processes and he attacked Head for implicitly accepting the image position for other psychological processes (1932, p. 200).

Operation of Schemas

In adopting the position that much of old knowledge was represented in the form of unconscious mental structures Bartlett had already made a major break with the image view. However, he also wanted to emphasize that knowledge was represented in larger units. Thus, he stated that schemas "operate, not simply as individual members coming one after another, but as a unitary mass" (1932, p. 201). Not only did he believe that schemas operated as larger units of knowledge, but he argued that schemas developed into qualitatively different cognitive structures. He stated that, "the past operates as an organized mass rather than as a group of elements each of which retains its specific character" (1932, p. 197).

By examining Bartlett's account of his memory data it is possible to infer what type of qualitative change Bartlett had in mind. He believed that schemas were generic mental structures. He assumed that in the course of exposure to many particular instances of phenomena the mind abstracted a generic cognitive representation (i.e., a schema). Bartlett often discussed this issue by comparing conventional modes of representing cultural artifacts in societies with conventional modes of representation within individuals. In one analysis of this issue he referred to the "stereotyped modes of representation or of reaction" of individuals and suggested that these "conventionalizations are produced by a combination of innumerable small changes" (1932, p.

95). Overall, a close reading of Bartlett suggests that he hypothesized schemas to be unconscious mental structures organized into generic cognitive representations.

In addition to these structural characteristics of schemas, Bartlett developed a number of proposals about schema processing. His fundamental processing assumption was that all new information interacts with the old information represented in the schema. This is one of the assumptions that Bartlett's theory and Head's theory had in common. In discussing postural change Head and Holmes had stated "Every recognizable change enters into consciousness already charged with its relation to something that has gone before" (Head, 1920, p. 605), and Bartlett quoted this section of their paper with approval. However, this is an aspect of Bartlett's approach to schemas that was present in his earlier work. In his first published experiment Bartlett explained errors made by his subjects in recalled visual figures by the interaction of new and old information. He stated that many of the errors were due to "the tendency to interpret presented material in accordance with the general character of earlier experience" (1916, p. 231).

In his later discussions of the interaction of old schema-based information with new input, Bartlett focused on the active nature of this process. He felt that earlier writers who had considered the role of old knowledge had treated the old information as a passive framework, somewhat like a partially

completed jigsaw puzzle capable of accepting the appropriate piece. Bartlett felt that the data in his memory studies were not consistent with a passive schema process. When he presented subjects with material to recall they made a large number of errors. Many of the errors were more regular, more meaningful, and more conventionalized than the original stimuli. Bartlett took these results to indicate that the subjects were actively attempting to relate the new material to old schema information--a process he called "effort after meaning." He stated that to accept the passive view "as if what is accepted and given a place in mental life is always simply a question of what fits into already formed apperception systems is to miss the obvious point that the process of fitting is an active process" (1932, p. 85). Bartlett typically gathered introspective reports during the recall process and on the basis of these protocols he concluded that the active processes were sometimes conscious strategies on the part of the subject (1932, p. 87-89), but more frequently he found them to be active unconscious processes (1932, p. 20).

Bartlett also thought that schema processes were generative, where generative means a process that can deal with an indefinitely large number of new instances. He was particularly clear on this characteristic of schema processing when discussing motor production schemas. Bartlett pointed out that a skilled tennis player is more likely to hit a tennis ball than an unskilled player, even when the ball appears in a new location

never before experienced by the skilled player. Thus, he argued that the old information accumulated by the skilled player is not in the form of a set of fixed motor movements, but in the form of a generative motor schema (1932, p. 202).

Bartlett's Memory Theories

The final aspect of Bartlett's schema theory that we will discuss in detail is his theory of the recall process. Bartlett actually had two different theories of recall. When he was talking abstractly and focusing on the mistakes of the storehouse or trace models he adopted a pure reconstructive model. However, when he was explaining his actual data he adopted a partial reconstructive model.

Pure reconstructive recall. The pure reconstructive model assumes that when an individual is exposed to some new information that new information serves to modify the appropriate schema, but that no specific episodic representation of the new information is retained in memory. Thus, for example, if someone goes into an office that they have never been in before, the information about that office will be integrated with the individual's established office schema and will modify that schema to some extent. Bartlett stated that the recall for a specific event, such as the visit to the office, is carried out by having "the organism . . . turn . . . round upon its own 'schemata'" (1932, p. 202). Many writers have felt that this aspect of Bartlett's theory was incomprehensible. It does not

seem so to us. If one reads this section of his memory theory in the context of his earlier published work and recognizes his concern with the issue of personal memory, then the problem Bartlett is dealing with becomes clear. He was concerned with providing an account of how an individual produces a specific memory representation from a generic schema representation. In the section of his book where he developed the pure reconstructive theory, Bartlett stated that an individual attempting to remember a specific event cannot base the recall on specific traces since "the individual details that have built them up have disappeared, but somehow /must/ construct or . . . infer from what is present the probable constituents and their order which went to build them up" (1932, p. 202). The pure schema reconstructive theory of recall succeeds admirably in dispensing with specific traces and gives a natural account of schema-based inferential errors in recall. However, it has a fatal flaw--it allows no recall of unique episodic information from the original episode. Thus, in the case of the earlier example of recall of an office, the pure reconstructive theory accounts nicely for the recall of generic schema information (e.g., typewriter, chairs) and provides an explanation of schema-based errors in recall (e.g., recalling books or filing cabinets when none were present--see Brewer & Treyens, 1981). However, the theory cannot account for the recall of specific nongeneric information about the room (e.g., that the typewriter was an

Underwood standard or that one of the chairs was made of plastic). Obviously, the pure schema reconstructive theory is in error. This is the natural consequence of combining a schema theory with a memory theory that allows no specific "trace" information whatsoever.

The problem of how specific memories are derived from generic schemas was discussed briefly by Bartlett. He stated that "somehow we have to find a way of individualizing some of the characteristics of the total functioning mass of the moment" (1932, p. 208). His solution was to suggest that "images are a device for picking bits out of schemas" (1932, p. 219). Most writers discussing Bartlett's theory have found these comments to be unintelligible. However, again we do not think that this is the case. Bartlett apparently assumed that specific memories are what Brewer and Pani (1983) call personal memories. A personal memory is a recollection of information from an individual's past that is experienced in terms of visual imagery and is typically accompanied by a belief that it represents a memory of a particular time and location (cf. Brewer & Pani, 1983, for additional discussion). If this analysis of Bartlett is correct, then his discussion of the issue makes much more sense. He was attempting to reconcile a memory theory based on unconscious schemas with the phenomenally experienced images of specific personal memories.

In a trace theory of memory, the memory theorist attempts to account for the recall of specific memories by some type of encoding and retrieval mechanism. Within the framework of the pure reconstructive theory Bartlett faces serious difficulties in providing a mechanism that produces specific memories from generic schemas. He stated that "specific recall is, in fact, an achievement of consciousness" (1935, p. 225). Although he gave no more details, he apparently felt that one of the major functions of consciousness was to allow an individual to generate specific phenomenologically experienced representations from unconscious generic schemas. He also suggested that the instantiation process was guided by the individual's "attitudes" (feeling and affect), but gave no clear account of how this process might achieve the desired result (cf., 1932, pp. 206-207). This is one of the only parts of Bartlett's memory theory that has not been followed up by later memory theorists (however, see Spiro, 1980).

Partial reconstructive recall. The pure reconstructive schema theory of memory that has been outlined above is Bartlett's "official" theory of memory--the one he presents overtly when he is describing the memory process in abstract theoretical terms. However, a close reading of Bartlett's accounts of his actual experiments reveals a partially reconstructive schema theory. This theory assumes that recall is a joint function of a schema component and a specific episodic

component. The motivation for the partially reconstructive theory apparently derives from certain aspects of his memory data. In a number of places Bartlett noted that there was recall of specific nonschema-related material. Thus, in an experiment on memory for visual symbols he stated, "The persistence of certain kinds of novel detail is an undoubted fact" (1932, p. 107). In his experiment on repeated reproduction of stories he noted that "as a rule one or two striking details seemed to recur with as little change as the form itself" (1932, p. 83). In an experiment on the serial reproduction of pictures, he pointed out that some nonschema details were frequently retained and stated that "This constitutes yet another case of that curious preservation of the trivial, the odd, the disconnected, the unimportant detail" (1932, p. 184). While Bartlett never overtly presented a theory that combines memory for specific information with his schema theory, he certainly suggested it in several places. In a discussion of inferences made in a memory-for-faces task he noted "that inferences, based upon judgements of this kind, are mingled unwittingly with the actual recall of perceptual material or patterns" (1932, p. 52). In a general discussion of imagery and schemas he noted that during recall "some part of the event which has to be remembered recurs, and the event is then reconstructed on the basis of the relation of this specific bit of material to the general mass of relevant past experience or reactions" (1932, p. 209). Thus, it seems to

us that when Bartlett was attempting to account for his own data and when he was not focusing on his opposition to trace theories that he implicitly held a partially reconstructive schema theory of memory. Almost all later schema memory theorists adopt a form of Bartlett's unofficial, partially reconstructive theory of memory.

Within the partial reconstruction position, there is a problem of the articulation of data and theory with respect to recall of nonschema information. Bartlett often found that nonschema information was not recalled (1932, p. 99) or was transformed to fit some schema (1932, p. 89); but on other occasions nonschema information was well recalled (1932, pp. 90, 184). Clearly, if a schema theory is to be explanatory it must be articulated in ways that give a motivated account of these apparently inconsistent data (see, Thorndyke & Yekovich, 1980, for a similar critique of modern schema theories).

In summary, Bartlett thought schemas were unconscious mental structures. He believed that they were organized generic mental representations that actively incorporated incoming episodic information. On the specific issue of recall, Bartlett's official position was a totally reconstructive theory, but in practice, he also held a partially reconstructive account of recall.

Bartlett, British Empiricism, and Continental Philosophy

This section attempts to answer the following puzzle: Bartlett's schema theory was published in 1932 and yet contemporary schema theory dates from 1975 (Minsky, 1975; Rumelhart, 1975). What caused the gap from 1932 to 1975? In order to answer this question it is necessary to take a brief metatheoretical detour. Mainstream American psychology in its early introspective form (e.g., Titchener) and its stimulus-response form (e.g., Watson, Hull, Skinner) was a direct descendant from the conceptual framework of British Empiricism.

For our purpose the canonical British Empiricist position concerning the structure of the mind can be characterized as: (a) Empiricist--all knowledge derives from the environment. (b) Atomistic--the mind is composed of simple elements. (c) Parsimonious--the mind is composed of a small number of basic types of elements. (d) Associationistic--the fundamental mental mechanisms are associations which form through spatial and temporal contiguity. (e) Particularistic--the basic elements are particulars (not true of Locke). (f) Passive--the mind is not active. (g) Mechanistic --the mind is not purposive, goal-directed, or irtentional. (h) Finite--no mechanisms are proposed that would be capable of dealing with an indefinitely large number of new situations. See Boring (1950), de Groot (1965), and Mandler and Mandler (1964) for a more detailed discussion of these positions. Continental philosophy (e.g., Leibniz, Kant,

Herbart, Lotze, Brentano) has not been as homogeneous as British Empiricism, but has tended to take the opposite side on these issues, thus the classic contrast between Empiricism and Rationalism. We will view each of the theoretical paradigms examined in this paper in terms of these fundamental assumptions. However, in doing this, we will not include the empiricist-nativist issue since it is rarely discussed by the theorists we consider. If we were to impose our own classification on these theories we would classify all the schema theories as nativistic since theorists who postulate as much mental machinery as schema theorists do are typically forced into a nativist position (e.g., Chomsky, 1965).

The British Empiricist position has a certain aesthetic appeal and has been the typical choice of the tough-minded theorist. Most behavioral scientists have considered the British Empiricist position to be the more "scientific" position. Thus, when American psychology shifted to Behaviorism, there was a drastic shift in the subject matter of psychology (from phenomenal experience to behavior), but no change in each of the assumptions outlined above. On these fundamental issues stimulus-response psychology was in total agreement with British Empiricism.

With this background in mind, it is now possible to examine the reception of Bartlett's schema theory. Bartlett's work had little impact on American psychology. In a review of the

Remembering book McGeoch said the experiments were, "outside the current of contemporary American research upon memory" (1933, p. 774), and in another review Jenkins concluded, "The book will find a place upon the shelves of those who study remembering, but it will not be in the special section reserved for those investigators whose writings have become landmarks in the advance towards the comprehension of this important problem" (1935, p. 715). In England, Bartlett's schema theory was taken much more seriously (e.g., Oldfield & Zangwill, 1942a, 1942b, 1943a, 1943b). However, even in England opinion shifted in the British Empiricist direction and by the time Bartlett died his major students considered the theory to have been a total failure (Broadbent, 1970; Oldfield, 1972; Zangwill, 1972).

We think a comparison of the assumptions of Bartlett's schema theory with the assumptions of British Empiricism makes very clear what the problem was--on almost all of the issues discussed above Bartlett's schema theory adopts the Continental position (see Table 1). On the issue of parsimony Bartlett does

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Insert Table 1 about here.

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take the British Empiricist position (one construct, the schema, does most of the work); however, on every one of the remaining issues Bartlett's theory is clearly on the Continental side. The intellectual roots of this heresy are to be found in Bartlett's

direct reading of the Continental philosophers, indirectly through the influence of James Ward and G. F. Stout, and through the work of the Wurzburg psychologists (see, Bartlett, 1936; Broadbent, 1970; Drever, 1965; Northway, 1940; Zangwill, 1972). Thus, Bartlett's schema theory was simply incompatible with the basic theoretical assumptions of the stimulus-response psychology that was dominant (in the United States) at the time he formulated the theory. In fact, one basic thesis of this chapter is that the history of the shifts from stimulus-response psychology to information processing psychology to schema theory is the history of a succession of psychologists who lust after the British Empiricist position but who have been dragged "kicking and screaming" by the brute facts of nature to the Continental position.

Information Processing Psychology

In this section we will briefly sketch some of the core theoretical assumptions made by theories in the information processing tradition, as background for the assumptions made by modern schema theories. By information processing theories we mean theories based on a computer metaphor that trace the flow of information in the mind through various stages of processing (e.g., Anderson & Bower, 1973; Atkinson & Shiffrin, 1968; Neisser, 1967; Newell & Simon, 1972). In terms of the contrast between British Empiricism and Continental philosophy, the information processing approach can be seen as a "profane union"

(Anderson & Bower, 1973, p. 4) of the two traditions. In shifting from stimulus-response theories to information processing theories, there was a continuing acceptance of some of the tenets of British Empiricism, but a rejection of a number of others.

First, we would like to know what information processing theorists consider their theories to be about (i.e., what ontological assumptions do they make?). This is a difficult questions, since many of the constructs used in these theories have been taken from computer science and artificial intelligence, and it is not clear how these borrowed constructs are to be interpreted in psychological theories (see Pylyshyn, 1978, and commentary). Thus, many theorists prefer not to address this issue directly or tend to be ambivalent when they do. Neisser's book, Cognitive Psychology (1967), was one of the major forces in molding the information processing paradigm. He argued that the "program analogy" makes it scientifically respectable to study unconscious mental processes (1967, p. 8). Thus, he apparently adopted the realist position that information processing theories are theories about the nature of unconscious mental processes. Quillian (1968) appeared to take a realist position, Collins and Quillian (1969) avoided the issue, but later Collins and Quillian (1972) appeared to take an instrumentalist position. Anderson apparently took a realist position with respect to the entities postulated in Anderson and

Bower (1973) but he took a radically instrumentalist position several years later (Anderson, 1976). (See Anderson's discussion of his change of view in Anderson, 1980, p. 85). Clearly the workers in the information processing paradigm have not reached a consensus on these difficult problems.

One of the major changes in the shift from behaviorist theories to information processing theories was the rejection of the assumption that the theories were about particulars. Information processing psychologists did not accept the assumption that psychological theories were restricted to observable behavior; and they included abstract entities in their theories (see Anderson & Bower's 1973 discussion of the "terminal metapostulate" issue).

Through the influence of generative linguistics (Chomsky, 1965), many information processing theorists came to realize that psychological theories need to provide an account of the ability of human beings to deal appropriately with "new instances" in language, perception, thought, and action. The researchers in the information processing tradition came to see that inability to deal with this aspect of human cognition was a fatal flaw in stimulus-response theories, and so they introduced abstract entities to allow some generativity.

Another fundamental shift made by information processing psychology was the abandonment of the belief that all psychological theories could be formulated in terms of

associations (see Anderson & Bower, 1973, for a contrary opinion on this point). Information processing theorists replaced the simple association with a wide variety of relational and structural entities: propositions (Kintsch, 1972); semantic relations (Quillian, 1968); and semantic features (Smith, Shoben, & Rips, 1974).

Some of the information processing theories avoided the general tendency of stimulus-response theories to be passive and nonpurposive, but there was not as much agreement on these issues. Thus, Newell and Simon 1972) provided explicit goal-directed problem-solving machinery that gave their theory a purposive component. Anderson and Bower (1973) chose to retain a passive memory representation ("strategy-free"), but include active processes in their executive component.

Two of the British Empiricist assumptions have been retained by the information processing approaches. All of the information processing theories have been atomistic and parsimonious. They have assumed that a complete theory of the mind could be constructed with a small number of basic mental elements. Holding to these assumptions has produced some interesting problems. For example, Anderson's (1976) theory combines the atomistic assumption with interference constructs to produce a "fan" hypothesis--which, put crudely, is that the more you know about a concept the slower and harder it will be to think about an instance related to that concept. While there is some support

for this hypothesis in laboratory list-learning tasks it seems highly unlikely that the fan effect occurs for real-world knowledge. If the fan effect does not hold up for real world knowledge (see Smith, 1981) then it would appear that theorists in this tradition will have to carefully examine their assumptions.

Overall, we think the picture is clear. Information processing psychology was a partial move toward the Continental tradition (see Table 1). The information processing theories rejected many of the British Empiricist assumptions of the earlier stimulus-response psychology, but retained a strong belief in atomism and parsimony.

Modern Schema Theory

It is clear that by 1975 there had been a Zeitgeist which prepared the cognitive science community for schema theory. In that one year papers were published arguing for schema theory by researchers in: artificial intelligence (Minsky, 1975); cognitive psychology (Rumelhart, 1975); linguistics (Fillmore, 1975); motor performance (Schmidt, 1975); and several artificial intelligence-cognitive psychology combinations (Bobrow & Norman, 1975; Schank & Abelson, 1975). It appears that the common issue that motivated investigators to look for a new theory was a desire to deal with "complex" tasks. The remarkable convergence of new papers in the same year was probably due to the fact that earlier versions of Minsky's important paper (1975) were widely

circulated in the period just before 1975. It is also interesting to note that every one of these papers makes explicit reference to Bartlett's (1932) schema theory—this only a few years after his major biographers had declared the theory to have been a failure (Broadbent, 1970; Oldfield, 1972; Zangwill, 1972).

Ontological Assumptions

On the issue of the ontological status of schemas it is hard to be sure what many schema theorists believe, and in those cases where the issue is treated clearly there is little consensus. Minsky (1975) and Rumelhart (1980) both define schemas as "data structures," a phrase that certainly has the flavor of a convenient notation to summarize the data (i.e., instrumentalism). Yet, the substance of both papers and Rumelhart's title, "Schemata: The Building Blocks of Cognition," certainly suggest they have more realist leanings. Neisser (1976) apparently takes a realist position and considers schemas to be physiological entities. He states, "a schema is a part of the nervous system. It is some active array of physiological structures and processes" (p. 54). Anderson (1981) takes a strong instrumentalist position. He suggests that the only solution to this problem is to "postulate some set of internal structures and processes that are consistent with the data and don't worry about unique identifiability" (p. 122). Problems concerning the status of theoretical entities are difficult for any science (Suppe, 1977); however, the issue seems particularly

acute in current cognitive psychology, since theories must find a solution for the treatment of psychological entities (e.g., images, intentions, thoughts, and unconscious mental processes) and for constructs borrowed from the area of artificial intelligence (e.g., data structures, nodes, arcs, and networks). See Pylyshyn (1978) and Thagard (1982) for a discussion of some of these problems.

Schema theories can be distinguished from information processing theories by one crucial characteristic--all schema theories reject the atomistic assumption. Schema theorists assume that there are some phenomena that cannot be accounted for by a concatenation of smaller theoretical constructs and that it is necessary to develop larger theoretical entities to deal with these phenomena. Aside from this one attribute, schema theories vary widely in the specific structures postulated and the theoretical emphasis given to particular problems. In order to display some of the overall properties of modern schema theories we will focus on two of the more general accounts of schemas--those of Minsky (1975) and Rumelhart (Rumelhart, 1980; Rumelhart & Ortony, 1977).

Minsky's Theory

Minsky (1975) is very clear about the rejection of the atomistic assumption. In the first two sentences of his paper he criticizes earlier theories for being "too minute, /and/ local" and argues that theories of the higher mental processes "ought to

be larger" (p. 211). The notion of a "larger" theory is hard to explicate purely in terms of the theoretical entities themselves. There is an additional assumption in the reasoning. This approach implicitly assumes that there are "larger phenomena" and larger theories are actually theories that deal with these phenomena. The nature of these "larger phenomena" can be seen from the examples given in Minsky's paper: perception of objects, perception of places, comprehension of discourse, comprehension of actions, and carrying out actions.

Minsky also states that the new theoretical constructs must contain more structure than those of earlier theories. He then goes on to provide some specific proposals about the type of structure needed. He introduces the construct of the frame (a type of schema in the terminology of this paper). A frame has fixed "nodes" that provide its basic structure. It has "slots" that can be filled by specific information from the environment. This provides additional structure, since a slot will only accept a particular class of instances. If there is no information to the contrary the slots are filled with "default assignments." With this type of theoretical machinery applied to knowledge about rooms, one could give an account of the following phenomena: (a) Someone walking into a room without a ceiling will be surprised. (b) People will not be able to understand the sentence "The ceiling is made of passive transformations." (c) Someone who had just been in a room might state that they had

seen the ceiling when eye movement recordings showed that they never looked up high enough to see the ceiling. (d) If asked to guess what a ceiling is made of, people will be much more likely to guess plaster than glass. (e) In a recall study some of the people who had been in a room with acoustic tile on the ceiling will recall that the room had a plaster ceiling (cf. Brewer & Treyens, 1981).

Minsky's theory was, in some sense, intended to be both a psychological theory and a theory in artificial intelligence. For the purposes of this chapter we have emphasized the psychological side of the theory. As a theory in artificial intelligence, the general outline Minsky supplied in his paper has been articulated in much greater detail (e.g., Bobrow & Winograd, 1977; Charniak, 1977). There are very thoughtful discussions of Minsky's theory, the relation of frames to propositions, and the implications of these issues for the philosophy of science in Thagard (1980, 1982).

Rumelhart's Theory

Rumelhart has provided a specific schema theory for the structure of stories (1975, 1977) and several papers on the general nature and functions of schemas (Rumelhart & Ortony, 1977; Rumelhart, 1980). We will focus on his general characterization of schemas. Rumelhart and Ortony (1977) clearly reject the atomistic assumption and explicitly point out that it is the attempt to handle all levels of abstraction including

"higher level conceptualizations" (pp. 109-110) that most clearly distinguishes schema theories from earlier information processing models. They state that "schemata are data structures for representing the generic concepts stored in memory" (p. 101). Rumelhart and Ortony follow Minsky in postulating that schemas have variables with constraints and that the variables have default values or, to be more precise, a distribution of possible default values. They point out that schemas are frequently defined in terms of other schemas ("schemata embed"). Thus, one's schema for an office building might include an office schema as a subpart. The office schema could function as a schema in its own right with a typewriter schema as a subpart, and the typewriter schema could function as a schema with keys as a subpart. In a more recent paper on schemas, Rumelhart (1980) emphasizes that schemas are active in the ways that procedures and parsers are active processes in computer programs.

In addition to the general characterization of schemas outlined above, Rumelhart has articulated some of the functions of schemas. In particular, he has attempted to clarify the interactions among the incoming episodic information, the generic information in the schema, and the specific nature of output. Rumelhart and Ortony (1977) state that "once an assignment of variable has been made, either from the environment, from memory, or by default, the schema is said to have been instantiated" (p. 105). These ideas are then used to develop a theory of the

memory process. Rumelhart and Ortony suggest that what gets stored in memory is an instantiated schema and that during the process of recall generic schema information may be used to further interpret and reconstruct a particular memory from the original instantiated schema record. In applying these ideas to the process of text comprehension, Rumelhart and Ortony focus on the interaction of "top down" schema information and "bottom up" text information. If a reader arrives at the schema intended by the author the text has been correctly comprehended. If the reader can find no schema to accept the text information the text is not comprehended. If the reader finds a schema, but not the one intended by the author, the text is misinterpreted.

Modern Schema Theory: Summary

Now having used Minsky's and Rumelhart's schema theories to instantiate modern schema theory, we will contrast the general characteristics of modern schema theory with the classic assumptions of British Empiricism. Clearly the major defining characteristic of schema theory is its rejection of the atomistic assumption. All schema theorists adopt what we will call the molar assumption. They assume that a schema theory needs to postulate "larger" theoretical entities and that these molar theoretical entities operate as units in the theory (cf. Anderson, 1980, p. 143; Charniak, 1977, p. 359; Minsky, 1975, p. 215; Rumelhart & Ortony, 1977, p. 106). A somewhat more extreme form of anti-atomism would be to argue that schema theories not

only need molar theoretical entities, but that these molar entities are qualitatively different from the smaller atomic entities in the theory. We will call this the assumption of "emergent levels." This issue is very similar to the debate about "mental chemistry" within the British Empiricist tradition. Thus, James Mill took a pure atomistic position and assumed that the more complex aspects of the mind were derived from different groupings of the basic mental atoms. However, his son, John Stuart Mill, adopted the emergent levels position and argued that the smaller mental atoms formed qualitatively new mental structures through the mental equivalence of chemical operations (see Boring, 1950, and Mandler & Mandler, 1964, for a discussion of this issue). Anderson (1981, p. 147) makes an explicit argument against the hypothesis of emergent levels. Most schema theorists have not overtly addressed this issue, but it seems to us that the decision to introduce new theoretical entities (frames, problem-solving schemas, etc.) is frequently an implicit acceptance of the hypothesis of emergent levels.

The desire for parsimony is the one characteristic of the British Empiricist paradigm that seems to us is still accepted in modern schema theory. An analysis of these theories gives the impression that many theorists are attempting to employ a particular kind of theoretical entity such as frames (Minsky, 1975), scripts (Abelson, 1981), or propositions (Anderson, 1981)

and use them to account for as wide a range of phenomena as possible.

The issue of associationism does not appear to be a live issue in schema theory. It seems highly unlikely that any schema theorists would think of themselves as "neo-associationists" as did Anderson and Bower (1973). The intellectual challenge has shifted from attempting to show that associations can handle everything to attempting to create some form of explicit theoretical machinery powerful enough to deal with the obvious capacities of the human mind (cf. Chomsky, 1965, p. 58 for a similar argument with respect to language acquisition).

One of the obvious characteristics of schema theories is the free use of generic and abstract theoretical constructs. In fact, one might want to argue that in some versions of schema theory the focus on generic information has been so strong that it is hard for the theories to deal with particular information. For example, at one point Neisser states that "perceivers pick up only what they have schemata for" (1976, p. 80).

Schema theories have worked hard to try and give an account of the apparently active aspects of human cognition. Minsky's (1975) frame theory, as originally presented, is more passive than are most other schema theories. However, Goldstein and Papert (1977) introduce the notion of "frame keepers" to deal with some of the more active aspects of the functioning of schemas. Rumelhart's 1980 modification of the earlier Rumelhart

and Ortony (1977) approach was an attempt to suggest some general techniques (procedures, parsers) for making schemas more active. Neisser's (1976) schema theory stands out from other recent proposals in that he not only treats the active aspects of schemas, but makes it their most important characteristic.

Typically, the theoretical machinery included in schema theories to deal with the active aspects of cognition also has a purposive flavor. Neisser's (1976) theory puts a strong emphasis on this issue. He states, "schemata are anticipations, they are the medium by which the past affects the future" (p. 22).

Schema theories have clearly recognized the problem of the generativity of cognitive processes (Minsky, 1975, p. 248; Rumelhart & Ortony, 1977, p. 112) and have made some suggestions about how to deal with this difficult issue. However, one has the feeling that most of these proposals are better discussions of the problem than successful solutions.

Bartlett and Modern Schema Theory

It is interesting to compare Bartlett's schema theory with the more recent schema theories. In terms of underlying motivation and overall structure the older schema theory and the newer schema theories are very close. Thus, Bartlett wanted a theory that emphasized the role of old knowledge and that dealt with molar cognitive phenomenon. He proposed a theory of organized generic schemas that function in a generative, active, and purposive fashion. Through the influences of linguistics,

information processing psychology, and artificial intelligence, modern schema theory has been able to develop more detailed and analytic accounts of the structure of schemas. In addition, these influences have enabled modern schema theory to more successfully deal with abstract, active, and generative theoretical entities. In recognizing the problem of accounting for specific personal memories within the framework of a schema theory Bartlett's position may actually be somewhat in advance of modern schema theories. On the particular issue of reconstructive memory, modern theories have not taken the totally reconstructive approach of Bartlett's "official" theory, but have developed partially reconstructive accounts that closely resemble Bartlett's "unofficial" theory. In summary, modern schema theories are very similar to Bartlett's theory, but have clarified, elaborated, and refined many aspects of his theory.

Information Processing Psychology and Modern Schema Theory

If one compares modern schema theory with information processing psychology on their basic theoretical assumptions, the overall intellectual trends are obvious (see Table 1). Schema theories are closer to the Continental side on these issues. The most striking difference between schema theories and information processing theories is the rejection of the atomistic assumption. On those issues where information processing psychology has shifted toward the Continental position schema theories have moved even more clearly and more firmly into the Continental

camp. The only major British Empiricist assumption retained by schema theory is the assumption of parsimony.

The Nature of Schemas

Ontological Assumptions

In this section we will discuss what we think schemas are. We believe a straightforward realist view is the correct way to approach the issue of the ontological status of schemas. We think that schema theories are theories about schemas and that schemas are the unconscious cognitive structures and processes that underlie human knowledge and skills. We believe that these mental entities have a physiological base, but that in the ultimate scientific account of things it will always be necessary to provide a scientific explanation at the level of mental entities (cf. Fodor, 1968; Putnam, 1973). We reject the instrumentalist option (Anderson, 1976, 1978) on a variety of grounds: (a) It seems inconsistent with our view that our goal as scientists is to search for Truth. (b) There are good arguments for realism (Suppe, 1977). (c) Realism has worked very well in the mature sciences. (d) As cognitive psychology matures it seems quite likely that there will be enough theoretical, empirical, aesthetic, and pragmatic constraints on our theories to undercut the indeterminacy arguments.

On the issue of the size of the mental "elements" we clearly favor the molar position. However, we think schema theories should explicitly adopt the more extreme view of emergent levels.

It seems to us that in human cognition there truly are emergent phenomena. Thus, in trying to give a scientific account of a spoken story, there are qualitatively different phenomena occurring at the level of the phonemes, at the level of syntax, and at the level of the plot; and it will require qualitatively different types of theories to deal with the different levels. Therefore we think the view that molar theories are simply sets of smaller elements operating as units is incorrect.

Modularity

The one tenet of British Empiricism that schema theories have not abandoned is the assumption of parsimony. We think that schema theories ought to make a clean sweep of the British Empiricist assumptions and adopt a liberal approach to postulating theoretical entities. It simply does not seem to us that a schema theory with a single schema construct can deal with the human abilities to: (a) understand a passage of expository text; (b) hit a tennis ball; (c) remember the shape of a leaf; (d) speak a sentence; and (e) remember the plot of a movie. Thus, we adopt the position that the mind is modular and that it will be necessary to develop different types of theoretical entities to account for the different cognitive processes (see Chomsky, 1980, for a similar argument). We realize that parsimony is an aesthetically pleasing attribute of a scientific theory and agree that it would be pleasing to find a parsimonious theory that accounted for all of the above phenomena. However,

given the current primitive state of schema theory, the assertion that a single type of theoretical entity can deal with all of the molar cognitive processes is just contrary to the facts.

It seems to us, that if one examines specific schema theories instead of general theoretical statements about schemas, that the many differences in the theoretical entities used in these specific theories is not in keeping with the parsimony assumption, but instead supports the modularity hypothesis. There appear to be strong similarities for the specific theories within a domain or module, but qualitative differences across domains. For example: scripts (Abelson, 1981; Graesser & Nakamure, 1982); plans (Lichtenstein & Brewer, 1980; Schmidt, Sridharan, & Goodson, 1978); scene schemas (Brewer & Treyens, 1981; Mandler & Ritchey, 1977); and motor schemas (Schmidt, 1975). Note also the recent theoretical controversy over the nature of story schemas (Black & Wilensky, 1979; Brewer & Lichtenstein, 1981, 1982; Mandler & Johnson, 1980). Brewer and Lichtenstein (1981, 1982) have argued that the story schemas proposed by researchers in the story grammar tradition (Mandler & Johnson, 1977; Stein & Glenn, 1979; Thorndyke, 1977) have actually been theories of the plan schemas that underlie the goal-directed behavior of the characters in narratives. Brewer and Lichtenstein argue that a theory of the story schema must contain theoretical constructs that deal with the discourse organizations that lead to particular affective states (1981,

1982), and must capture culture-specific literary conventions (Brewer, in press). If Brewer and Lichtenstein are correct, then one needs very different types of theories to deal with goal-directed behavior and with the structure of stories. Thus, overall it seems to us that in the actual practice of constructing specific schema theories one finds considerable support for the modularity position.

Ecological Validity

Many schema theorists have made arguments in favor of "ecological validity" (e.g., Bartlett, 1932, pp. 17, 47; Brewer & Treyens, 1981, p. 207; and Neisser, 1976, for a very strong form). The general approach has been to assert that cognitive psychology should not study narrow laboratory tasks, but should study tasks that occur in real life. In the course of developing the analysis of schema theory outlined above, we have come to believe that the argument for ecological validity is not correct as usually stated. It is not that studies of phenomena from everyday life are somehow intrinsically better than narrow laboratory studies. Instead we think the intuition behind the ecological validity position derives from the issues of emergent levels and modularity of mind. If one accepts the argument for emergent levels and/or the modularity thesis, then focusing on a few narrow laboratory tasks becomes a highly dangerous research strategy. If either of these two assumptions is true, then no matter how much effort is put into the study of nonsense

syllables or eyelid conditioning it cannot ever result in a comprehensive theory of the mind. On the other hand, if one adopts the research strategy of studying a wide range of everyday tasks, one is much more likely to find phenomena from qualitatively different levels or from different cognitive domains. Thus, the research strategy of focusing on ecologically valid tasks should not be driven by the everyday nature of the task (clearly one can learn much about the mind from some narrow laboratory tasks), but by the recognition of the research implications of accepting the emergent levels and modularity positions. Bartlett worked out part of this logic in his introductory section on methodology (1932, pp. 2-7).

Phenomenal Experience

A final issue that we think needs to be addressed by schema theory is the relationship between schemas and phenomenal experience. It is clear why this problem has been avoided. For the earlier behaviorists there was no problem, since they explicitly excluded the data of phenomenal experience from a science of behavior. The main focus of information processing psychologists was on unconscious mental processes. Therefore they tended to ignore the data of phenomenal experience, or to argue that the experience itself was of little interest to information processing psychology as compared to the underlying unconscious cognitive processes (e.g., Pylyshyn, 1973). Schema theorists have also focused on the unconscious mental processes

of the schema and ignored the problems of consciousness and phenomenal experience (e.g., Rumelhart & Ortony, 1977). Minsky (1975) discusses the problems of imagery and consciousness at various points in his frame paper, but never explicitly related these issues to the frame construct. The one schema theorist who was an exception to this trend is Bartlett. He concerned himself with these problems at length in his book (1932), and he was particularly concerned with trying to work out a solution to the apparent inconsistency between his pure reconstructive schema theory and the particular experiences that are involved in personal memories (see the discussion of Bartlett in the first section of this paper).

In a recent paper Brewer and Pani (1983) bite the bullet on this issue. They argue that an ultimate scientific psychology must account for the data from phenomenal experience, just as it must account for the data of performance. If, for example, the data from experience and from performance on some task are "inconsistent" one does not throw out the pehnomenal data because it is somehow less scientific. Instead the science of psychology must aspire to explain all of the data. As an example of the problem in the area of memory, Brewer and Pani (1982, in preparation) show striking differences in the phenomenal reports of imagery for different types of memory tasks. They argue that a complete theory of memory must give an account of this experiential data in addition to the usual memory performance

data. The general issue of the relation of conscious and unconscious processes is a pervasive one for cognitive psychology. We will discuss three examples that relate directly to schema theory.

Personal memory. First is the problem of personal memory. There is an apparent tension between schema theories and the experience of personal memory. Schema theories focus on generic knowledge and the schematization of incoming episodic information. Yet when one has a personal memory (e.g., "Where were you the last time you spent cash for something?") there is a strong phenomenal experience of imagery and the imagery appears to contain "irrelevant" details of the original experience. Clearly, as Bartlett recognized, schema theory must deal with this problem (see Brewer & Pani, 1983, and Neisser, 1982, for somewhat different ways of approaching this issue).

Generic images. A second problem is that of generic images. Many types of generic knowledge processes appear to operate with little concomitant phenomenal experience (e.g., "What is the opposite of falsehood?"). However, repetitive experience with visual perceptual information leads to generic knowledge structures that have strong visual image properties (e.g., "What hand does the Statue of Liberty hold the torch in?"). How is this fact to be dealt with in schema theory? One could say that the true schema in these cases is an unconscious generic structure and that the phenomenal experience is an epiphenomenon.

One could take a strong imagist view and say that the phenomenal experience is the schema. Or one could say that it is necessary to postulate both an underlying unconscious schema and a phenomenally accessible generic mental image (cf. Brewer & Pani, 1983). For our purpose here, it is not important to decide which of these is the correct view. The point is, that schema theory must overtly address this type of issue.

Procedural information. A final example is the strong phenomenal experience that accompanies the transfer of procedural knowledge into semantic knowledge [two examples: (a) "What is the 8th letter of the alphabet?"; (b) "What finger do you use to type 'r' with?"]. The difference in phenomenal experience is striking. When a skilled task (motor, cognitive, or rote linguistic) is carried out there is little or no phenomenal experience of imagery. Yet, in order to answer a propositional question about the information contained in the procedure there is a strong experience of imagery (cf. Brewer & Pani, 1983). Clearly, the problem is to explain these facts. Why are the production schemas normally unconscious? Why does the propositional task give rise to powerful imagery experiences? Does one want to say that the imagery is causal in the performance of the task?

It seems to us that examples such as these lead to an obvious conclusion. Schema theory must take the data from phenomenal experience seriously and schema theory must be

articulated so that there is a graceful fit of the facts from phenomenal experience. These are difficult problems and we cannot provide solutions here, but we do have a suggestion as to the direction of theory development. Perhaps one can adopt the position that the schema structures and the processes operating on the structures are unconscious, but that the products of these operations are conscious. This is similar to a position taken by Lashley (1960) and, of course, somewhat similar to Bartlett's discussion of these issues. The type of conscious product seems specific to the particular cognitive domain involved. Thus, the memory processes relating to particular perceptual inputs seem to give rise to modality specific imagery (e.g., visual imagery for visual perceptual input), whereas the cognitive operations involving abstract thoughts or practiced skills seem to give rise to other types of nonimage conscious products (see Brewer & Pani, 1983, for further discussion).

Definition of Schema

In light of this analysis of schema theory, what are schemas? Schemas are the unconscious mental structures and processes that underlie the molar aspects of human knowledge and skill. They contain abstract generic knowledge that has been organized to form qualitative new structures. Schemas are modular--different cognitive domains have schemas with different structural characteristics. At input, schemas actively interact with incoming episodic information. This interaction consists of

two basic processes: (a) the modification of the generic knowledge in the relevant schema; (b) the construction of a specific instantiated memory representation. An instantiated schema is a cognitive structure that results from the interaction of the old information of the generic schema and the new information from the episodic input. The generic schema contains some fixed structural relations and some slots that accept a range of specific input information from the environment. The unconscious operation of the schema gives rise to the specific conscious contents of the mind. At output, generic production schemas interact with new incoming information to allow appropriate responses to an indefinite number of new situations.

In informal interactions with colleagues from the stimulus-response and information processing traditions it is obvious that they consider schema theory to be a vague and "soft-headed" theory. Why is that? We think that there are several reasons that derive from the world view of the critics and several reasons that derive from the current status of schema theory. The first cause of this attribution is, of course, the result of the wholesale adoption of the Continental position by schema theory. From the British Empiricist point of view the Continental position has always seems vague and soft-headed. The second reason is a matter of temperament in theory construction (not unrelated to the Empiricist-Rationalist issue). Some theorists prefer a precise, completely worked-out theory even if

it is obviously wrong. Other theorists prefer a theory that is not obviously false, even if this means having only a sketch of an account of the phenomena at hand. Herbert Feigl once referred to this difference in scientific temperament as the great split between the "nothing but" theorists and the "something more" theorists. Clearly schema theory falls in the "something more" camp.

The other two reasons for the perception of schema theory as vague arise from true problems with the theories in their current stage of development. First, the attempt to hold to the ideal of parsimony has caused problems in trying to give a general characterization of the nature of schemas. If one rejects the parsimony assumption and accepts the arguments for modularity, then a general account of schemas must look vague. Such an account can only focus on the characteristics that the general class of molar cognitive structures have in common, and so cannot be too precise without running up against obvious counterexamples. On the other hand, consistent with the modularity thesis, it is much harder to accuse specific schema theories in particular domains of being vague compared to other theories in psychology (Graesser & Nakamure, 1982; Lichtenstein & Brewer, 1980; Rumelhart, 1977). Finally, it is obvious that modern schema theory is still immature and in need of further development (see Thorndyke & Yekovich, 1980, for a similar analysis). Clearly, there is much work ahead in this area. In

fact, there are some really hard problems for schema theory that we have not even mentioned. For example: How do schemas develop? How does incoming information activate an appropriate schema? What are the correct structures for schemas in different cognitive domains? Nevertheless, even in its current state of development, it seems to us that schema theory is one of the important currents in psychology and the larger cognitive science community. In keeping with this discussion of schema theory we will attempt, in the last section of this chapter, to articulate and make more precise one aspect of schema theory—the role of schemas in the memory process.

The Functions of Schemas in the Memory Process

Basic Schema Findings

First we will examine a set of basic empirical findings in the study of human memory that set the stage for our analysis. It is experimental results such as these that seem to require a schema theory account of human memory. We will refer to the results of these experiments as the "basic schema findings."

Memory with and without schemas. There are a great variety of different experiments which can be used to show that information which can be instantiated in a schema is better recalled than information which cannot easily be instantiated in a schema. In fact, the very first experiment on human memory shows this effect. Ebbinghaus (1885/1964) found that recall for information from a lyric poem was about ten times better than

recall of nonsense material. By 1937 there had been many experiments on this issue, all leading to the general conclusion that recall of meaningful material was much better than recall of meaningless material (Welborn & English, 1937). In these older experiments the meaningful materials are very different from the meaningless materials along many dimensions. In more recent times, experimenters have found techniques to show the schema effect with materials in which the basic elements are the same, or even with the use of only a single passage to yield the schema effects. Examples of modern studies showing that recall is better for material which can be instantiated in a schema are: (a) standard text vs. scrambled text (Brent, 1969; Chiesi, Spilich, & Voss, 1979; Lachman & Dooling, 1968; Thorndyke, 1977); (b) picture before opaquely written passage vs. picture after the passage (Bransford & Johnson, 1972); (c) title or theme before opaquely written passage vs. after the passage (Bransford & Johnson, 1972; Dooling & Lachman, 1971; Dooling & Mullet, 1973; (d) recognition of organized pictures vs. disorganized pictures (Mandler & Johnson, 1976; Mandler & Ritchey, 1977); (e) canonical videotaped actions vs. scrambled actions (Lichenstein, 1979).

Subject knowledge and recall. Another way to show the general effects of schemas is to compare the differences in recall for subjects who come to the experiment with different degrees of schema-based knowledge. The basic finding is that subjects with a more developed schema for some body of knowledge

show higher recall for materials related to that knowledge. Studies showing this effect include: recall of chess positions by expert chess players vs. novice players (Chase & Simon, 1973); recall of a baseball narrative by individuals with high and low knowledge of baseball (Chiesi, Spilich, & Voss, 1979); recall of narratives about Western and Australian Aboriginal medicine by Western and Australian Aboriginal subjects (Steffensen & Colker, 1982).

Memory for schema-related information. One of Bartlett's (1932) original findings dealing with the recall of text was that information connected with the underlying theme or plot of the passage was more likely to be recalled than was information not connected to the theme. This basic finding, that schema-related information will be recalled better than schema-unrelated information, is a very robust finding and has been replicated many times by a great number of researchers using a wide variety of theories about the nature of the underlying schemas (Brewer & Treyens, 1981; van Dijk & Kintsch, 1978; Gomulicki, 1956; Goodman, 1980; Johnson, 1970; Lichtenstein & Brewer, 1980; Mandler & Johnson, 1977; Meyer & McConkie, 1973; Rumelhart, 1977; Thorndyke, 1977).

Schemas and the Memory Process

The basic schema findings outlined above can be accounted for by any of the schema theories discussed earlier. The ability to deal with this body of experimental findings is one of major

reasons for the rapid development of schema theory in psychology in recent years. However, it seems to us that accounting for these basic schema findings is not enough. It is necessary to develop much more explicit and precise theories about the operation of schemas in the memory process. We will attempt to work out a more detailed understanding of the role of schemas in memory by focusing on two questions: (a) In a given memory task how much of the subject's memory is due to generic schema information and how much is due to episodic information? The term "episodic" is not intended to carry any theoretical implications, e.g., Tulving, 1972, but is merely a descriptive term used to indicate the information actually obtained from the environment during a particular exposure). (b) What are the mechanisms through which schemas operate in the memory process?

We propose that there are five basic processes through which schemas could operate during the memory process (these schema-based operations are extensions of the processes outlined in Brewer & Treyens, 1981): (a) Schemas could influence the amount of attention allocated to a particular type of information, with the assumption that more attention leads to better memory. (b) Schemas could operate as a framework in memory that serves to preserve incoming episodic information. (c) Generic schema information could interact with incoming episodic information to produce a memory representation that is a combination of old generic information and new episodic information. (d) Schemas

could serve to guide retrieval processes in order to locate episodic information in memory. (e) Schemas could operate to influence what retained information a subject chooses to produce in a memory task.

In the remainder of this section we will examine the experimental literature to see if we can find unambiguous evidence to support the position that schemas operate through the mechanisms discussed above. Since the basic schema findings could result from any of the five schema-based processes we will attempt to use a substractive logic. For each set of data discussed, we will try to show that the results must have been due to a particular process because we can rule out all of the other alternatives. Note that in our analysis we frequently claim that a particular experiment supports positions quite different from that proposed by the authors. We will work our way through the five basic schema processes in the order given above, and for each process we will treat experiments dealing with linguistic materials first and those using nonlinguistic materials second.

Attention

The basic assumption of the attention mechanism as applied to memory is that increased amounts of attention lead to a stronger memory trace. In order to relate this mechanism to schema-based processes one has to work out the relation between attention and schema-based information. Currently this is an

area of some confusion. A number of researchers have postulated that schema-related information receives more attention than schema-unrelated information (Bower, 1976; Cirilo & Foss, 1980; Kintsch & van Dijk, 1978). However, in direct contrast to this position, a number of other researchers have postulated that schema-related information receives less attention than schema-unrelated information (Bobrow & Norman, 1975; Friedman, 1979). Notice that a memory theory that only allows schemas to operate via attention, and makes the assumption that schema-related material receives less attention, cannot account for the basic schema findings, since it would have to predict poorer recall for schema-related material. However, as we will see, it is possible to combine the hypothesis of less attention to schema-related information with other schema-based memory processes to give an account of the basic schema findings. Of all the schema-based memory processes to be discussed the attention mechanism is the hypothesis with the least amount of theoretical and empirical consensus.

Linguistic materials. There are empirical studies with text materials that support both positions on the schema-attention issue. Cirilo and Foss (1980) find longer reading time (and thus presumably more attention) for schema-related information, while Shebilske and Reid (1979) find the reverse. This is too complex an issue to analyze here, but it seems to us that the general direction that must be taken is to provide a much more

sophisticated account of the interaction between the reader's developing mental model and the structure of the text (see Rumelhart, 1980). In dealing with text one has to take into account the fact that the author has complete freedom to manipulate the text structure by including, omitting, or reordering any aspect of the underlying schema-based information (see Brewer, 1980). Within this framework, a simple analysis into schema-related information and schema-unrelated information (or as frequently described, high in the text hierarchy and low in the text hierarchy) probably does not cut the world in the appropriate fashion. We will present a brief example to illustrate the complexities of this issue. Imagine a story about a racing car driver. First we, will examine schema-related information: If the author has chosen to include in the text schema-based information that is easily available from the reader's schema then one might expect the reader to devote less attention to it. For example, "The driver turned the steering wheel to the right. The car went around the turn to the right." However, for schema-related material that is informative about the plot one would expect the reader to devote more attention, e.g., "The accident had left a huge oil spill on the far turn." Now we will examine schema-unrelated information: If the schema-unrelated information is <u>irrelevant</u> to the plot, then one would not expect readers to devote much attention to it, e.g., "The driver put his candy wrapper in the trashcan." However, if the

schema-unrelated information is inconsistent with the developing mental model about an automobile race, then one would expect the reader to devote considerable attention to the anomalous information in order to try and instantiate it into the developing mental model, e.g., "A man in the stands stood up, pointed his finger at one of the cars, and it turned into a giant Twinkie." Thus, while it appears that there are schema-based attention processes, it also seems that a full analysis of attention and schema relatedness will have to incorporate an account of the relation of text information to schema information, and an analysis of reading, that views the reader as using text information to develop a mental model during the course of reading the text.

Even though the current state of our knowledge about schema-based attention processes is poorly developed, there is some reason to believe that the attention process is not the major determiner of the schema-based recall findings. A number of studies using a variety of techniques have attempted to control the attentional processes and have found that this has little effect on schema-based memory findings (Britton, Meyer, Simpson, Holdredge, & Curry, 1979; Graesser, Gordon, & Sawyers, 1979; Graesser, Nakamura, Zimmerman, & Riha, 1980; Johnson, 1970; Reynolds, 1979).

Nonlinguistic materials. Several studies have examined the number and duration of eye fixations on schema-related and

schema-unrelated information in viewing pictures. The general finding is that subjects devote more attention to schema-unrelated information (Friedman, 1979; Loftus & Mackworth, 1978). Friedman's (1979) study makes an important distinction between schema-irrelevant information and schema-inconsistent information. She finds a strong initial effect of long fixations for schema-inconsistent information and a small tendency for schema-irrelevant information to have longer fixations than schema-relevant information.

Overall, it appears that there is some agreement that subjects direct attention to schema-inconsistent information. It appears that the resolution of the issue of the amount of attention directed at schema-relevant vs. schema-irrelevant information may require that this dichotomy be replaced with a much more complex, and perhaps domain-specific analysis of reading text and of viewing the visual world.

Framework

The framework hypothesis states that schemas can serve as a scaffolding to preserve schema-related episodic information. It is easy to conceptualize this mechanism in terms of Minsky's (1975) theory of a frame with slots that accept a range of possible values. In these terms the framework view states that instantiating a slot with a particular piece of episodic information will tend to preserve the memory trace for that information. The framework hypothesis predicts that new schema-

related information will be better retained than new schema-unrelated information. In order to show that this effect is due to a preserved episodic trace one must rule out other schema-based mechanisms such as integration or retrieval. Note that the framework hypothesis, as stated, makes no assumption about the level of information that is preserved by the framework. The preserved episodic information could be fairly low-level perceptual information ("surface information") or much more abstract information.

Linguistic materials. The studies showing the effect of a picture or title on the recall of an opaquely written passage (Bransford & Johnson, 1972; Dooling & Lachman, 1971; Dooling & Mullet, 1973) can be interpreted as supporting the framework hypothesis. In these studies the subjects who received a schema-envoking picture or title before they heard the passage showed much better recall than subjects who received the picture or title after they heard the passage. If the effect had been due to old schema knowledge (integration) or to the schema operating as a retrieval mechanism, then the subjects who received the schema afterward could have used the schema to make inferences or as a retrieval device just as well as the subjects who received it first. Since the data show a large difference in recall between the two conditions, it appears that the schema is operating as a framework to preserve the episodic information contained in the passage.

Another study that can be interpreted as support for the framework hypothesis is a text recall study by Thorndyke (1977). In this study Thorndyke compared recall for two types of embedded goal-based passages, one with the superordinate goal at the beginning and one with the superordinate goal at the end (in texts of this kind, when the goal comes first the reader can understand the purpose of a rather strange sequence of actions). Recall was better for the group that received the goal at the beginning of the passage, and through our subtractive logic we interpret this finding to support the position that schemas can act as a framework to preserve information from texts.

Nonlinguistic materials. There are a number of studies of picture memory by Mandler (Mandler & Johnson, 1976; Mandler & Parker, 1976; Mandler & Ritchey, 1977) which can be interpreted as evidence for the action of schemas as frameworks to preserve episodic picture information. Two types of pictures are used in these studies--organized and unorganized. An organized picture consists of a small number of schema-related objects spatially arranged to make up a schema-consistent visual scene. The unorganized pictures consist of the same objects rearranged to give a schema-inconsistent visual scene (e.g., a desk in the upper part of the picture not resting on any solid surface). Memory for the information in the pictures (objects, spatial relations) was tested with a recognition procedure in which the foils for the organized pictures were changed from the original

picture but were schema-consistent. In general, these studies showed that recognition memory was better for organized pictures than for unorganized pictures. The use of schema-consistent foils eliminates the possibility that the subjects are responding on the basis of generic knowledge, and the use of a recognition memory procedure reduces or eliminates the use of schemas as retrieval mechanisms, so we believe this finding can be used to show that schemas operate as frameworks to preserve episodic information.

Thus, overall we find that there is evidence from both linguistic and nonlinguistic domains for schemas operating as frameworks to preserve episodic information.

Integration

The integration hypothesis states that during the process of schema instantiation old schema-based information becomes integrated with new episodic information. Thus, the instantiated memory representation will contain both generic information from the schema and episodic information from the input. The proportion of generic information and episodic information will vary with factors such as the type of schema and time interval test. The most extreme form of integration would be the case where all the episodic information was lost from memory so that the memory response would be based completely on generic information. If integration occurs, then it will lead to apparently better memory for schema-related information than for

schema-unrelated information since the memory for schema-related material will actually be based on a mixture of generic schema information and episodic information. When a subject gives information in recall that comes from the generic schema and was not in the episodic input, then we say that an inference has occurred. The occurrence of schema-based inferences in a recall task or false recognition responses to schema-related foils on a recognition task is a qualitative indication that the process of integration has occurred. And when this occurs one can be almost certain that some proportion of the apparent episodic memory for presented schema-related items actually derives from generic schema knowledge. For the purposes of this general definition of integration, it does not matter if the interaction of old and new information occurs during comprehension or during testing or how conscious the subject is of the integration process.

Linguistic materials. Evidence for integration in memory for textual material is widespread. In one of the very first text-memory experiments ever performed, Binet and Henri (1894; translated in Thieman & Brewer, 1978) found examples of integration. They noted, for example, that one child recalled "for her animals" as "for her rabbits" and they argued that these "errors of imagination" were obviously due to the child's background knowledge. Bartlett (1932) also noted the process of integration in his story recall data. He stated that he deliberately chose to use somewhat unusual stories (Kathlamet

Indian texts) as materials so that he could look for inferences driven by the schemas that his English undergraduates brought to bear on the texts. He obtained the expected data and gave as an example the fact that one of his English subjects recalled "paddling a canoe" (from the Kathlamet text) as "rowing a boat."

One of the first modern studies to focus on inferences in text memory was the study of Sulin and Dooling (1974). In this study subjects heard a passage and were later given a recognition memory test. Some of the subjects were told that the passage was about Helen Keller and these subjects showed a strong tendency (after one week) to make false recognition responses to nonpresented sentences such as one stating that the main character was blind. In more recent times there have been a number of studies of memory for script-based texts (Bower, Black, & Turner, 1979; Graesser, Gordon, & Sawyer, 1979; Graesser, Woll, Kowalski, & Smith, 1980--reviewed in Graesser, 1981 and Graesser & Nakamura, 1982). These studies have shown a very high rate of script-based intrusions and false recognitions of script-based foils. In one of these studies (Graesser, Woll, Kowalski, & Smith, 1980), the researchers used the evidence of script-based inferences to argue that much of the memory advantage for script-related items at one week was due to script-based information and not to episodic information. Another recent study showing evidence for integration is the work of Chiesi, Spilich, and Voss (1979) on memory for texts about baseball games. These

researchers found that subjects made many false recognition responses to nonpresented items relating to the baseball schema.

A number of experiments have varied the retention interval to study schema-based memory processes over time. These studies have found that the integration effect becomes stronger over time (van Dijk & Kintsch, 1978; Graesser, Woll, Kowalski, & Smith, 1980; Spiro, 1977; Sulin & Dooling, 1974). Presumably, this effect is due to the differential loss from memory of different types of information. At immediate testing there is apparently some retained information about the particular propositions from the initial text. Over time, this type of "surface" information is lost leaving the instantiated schema in memory, and after very long time intervals much of the episodic information in the instantiated schema may be lost, leaving predominantly generic schema information.

Nonlinguistic materials. A series of recent studies provide evidence for integration in memory tasks using visual perceptual input. Jenkins, Wald, and Pittinger (1978) presented subjects with a series of pictures that described an event. The subjects showed a large number of false recognition responses to schema-based items that belonged to the event but that had not been shown in the original sequence. Loftus, Miller, and Burns (1978) have shown that giving subjects (false) verbal information about an event previously seen by the subjects can lead subjects to make false recognitioni responses to pictures that they have

never seen before. Brewer and Treyens (1981) obtained evidence for integration in a naturalistic study of memory for rooms. The subjects were asked to wait in an office briefly, on the pretext that the experimental apparatus was not ready. Then the subjects were taken to another location and given a series of recall and recognition tests for information about the room. In recall the subjects reported a number of objects that were not in the experimental office. These inferred objects were all highly related to the office schema. On a verbal recognition test (e.g., "Did you see a typewriter?") there was a high positive correlation between the schema-expectancy scores from a different group of subjects and the verbal-recognition scores for nonpresented items from the group of subjects who saw the room. Since this correlation was based on recognition ratings of items the subjects never actually saw, it must have been based on the subject's office schema.

A series of experiments using nonlinguistic materials have investigated the role of the retention interval in schema-based integration processes. These studies, like the linguistic studies discussed earlier, have shown that the integration effect becomes stronger over time (Brewer & Dupree, 1983; Mandler & Parker, 1976; Mandler & Ritchey, 1977). The explanation for these effects is essentially like that proposed for the studies using linguistic materials. Different types of information are apparently lost from memory at different rates over time. Thus,

at short time intervals, there is some retained perceptual information about the visual scene, and over time this specific episodic information is lost and memory performance is increasingly based on the instantiated schema and generic schema information. Brewer and Dupree (1983) suggested that for hierarchically organized plan schemas the information is lost from the bottom up, leaving successively more abstract information about plans and goals in memory at longer time intervals.

Overall, there is much evidence for integration in memory for both linguistic and nonlinguistic material. The size of the effect seems to vary widely depending on the "strength" of the particular schema. Thus, scripts seem particularly powerful in producing inferences. In all of these domains there is a tendency for integration to be much stronger at longer time intervals. As the specific episodic information is lost over time, the underlying generic information plays a larger role in the memory task.

Retrieval

The retrieval hypothesis states that schemas may operate to guide the memory search for schema-related episodic information. This hypothesis predicts better recall of schema-related than of schema-unrelated information. For a schema-related item and a schema-unrelated item of equivalent memory-trace strength (as tested by recognition memory) the retrieval hypothesis predicts

that the schema-related item is more likely to be given in a free recall task.

Linguistic materials. Two studies by Anderson and Pichert (1978) and by Pichert and Anderson (1977) can be interpreted as support for the use of schemas as retrieval devices. Subjects in these studies read a text that could be viewed from two different viewpoints (schemas). Thus, for example, one text was about a house and its contents and could be viewed from the point of view of a home buyer or a burglar. Subjects who took a particular perspective (e.g., burglar) tended to recall more schema-related information (e.g., location of the family silver). After recall from one perspective, subjects were asked to recall the story a second time from the other perspective, and under this schema-based perspective, they recalled some of the now schema-related information that had previously been schema-irrelevant. Thus, it looks as if the perspective manipulation acts to provide a schema-based retrieval plan. There have been other interpretations of these findings (Wyer, Srull, Gordon, & Hartwick, 1982).

Nonlinguistic materials. Lichtenstein and Brewer (1980) carried out a series of studies showing that plan schemas have powerful effects on the recall of goal-directed actions (i.e., actions that are part of a plan schema are recalled better than actions that are not part of a plan schema). However, Lichtenstein and Brewer only used recall measures which, by

themselves, are not sufficient to establish what mechanism was producing the facilitation in recall for plan schema items. Brewer and Dupree (1983) used a variety of recall and recognition tasks to attempt to give a more analytic account of the findings of Lichtenstein and Brewer (1980). They compared recall of actions that were seen embedded in a plan schema (e.g., reached up with a ruler to adjust the hands of a high clock) with the same actions not embedded in a plan schema (e.g., reached up with a ruler). They found that immediate recall for an action was more than twice as good if it occurred in a plan schema. However, they also found that on an immediate visual recognition test the two types of actions were recognized equally well. Thus, for actions equally well recognized many more of the schema-related items were given on the recall task. Brewer and Dupree argued that this pattern of results indicates that the plan schemas were operating as a retrieval mechanism to allow access to a greater portion of the plan-related episodic information.

Brewer and Treyens (1981) have used similar logic to investigate memory for places. For the objects in a room that were strongly recognized in a verbal recognition task, the schema-related objects were much more likely to have been written down in recall than were schema-unrelated objects. Brewer and Treyens argued that this result indicated that some of the better recall for schema-related items must have been due to the office

schema being used as a retrieval device. Thus, our analysis of these studies indicates that schemas can function as retrieval mechanisms.

Editing

The editing hypothesis states that schemas may operate outside of the memory mechanism itself to determine which information the subject chooses to communicate to the experimenter. Thus, if the experimenter instructs the subject to recall "just the basic ideas," the subject might use schema knowledge to identify the schema-relevant information and choose to write down only the schema-relevant information. This use of schemas to edit memory output gives apparently better recall for schema-related material.

Linguistic material. In terms of the actual experiments there is evidence for schema-based editing, but it operates to reduce recall of very high schema-related information. Graesser, Woll, Kowalski, and Smith (1980) found that subjects in a script generation task tended not to produce very typical script actions. Brewer and Treyens (1981) argue that this type of finding follows from an analysis of the recall task as one in which the subject is communicating with the experimenter. The subjects apparently are following a conversational maxim (Grice, 1975) that one should not tell someone information that is completely obvious.

Within the story grammar tradition (Mandler, 1978; Mandler & Johnson, 1977; Stein & Glenn, 1979) there is a recall finding that can be given a similar interpretation. In producing texts to fit particular theoretical models the researchers in this tradition have often violated the maxim that an author should not include in the text information that is obvious to the reader. In particular, a number of story grammar researchers have included in their texts a category called "reaction" or "internal response" or "internal plan." By including these categories one can obtain texts such as, "After the argument with his boss Joe was angry /reaction/ so he decided to slam the door as he left the office /internal plan/. He slammed the door as he left the office," instead of the more natural, "After the argument with his boss Joe slammed the door as he left the office." One of the major empirical findings of the story grammar tradition (Mandler, 1978; Mandler & Johnson, 1977; Stein & Glenn, 1979) has been that information relating to reactions or internal plans is very frequently lost in story recall tasks. It seems to us that this memory data is actually produced by the operation of schemas to edit information that is redundant with the actions described in the narratives (see Black & Wilensky, 1979; Brewer & Treyens, 1981, on communication; and van Dijk, 1980, p. 262, for further discussion of this editing process in recall tasks).

Nonlinguistic materials. Brewer and Treyens (1981) found evidence that schemas were being used to edit out some of the

very high schema-related information in their naturalistic room memory study. Subjects rarely recalled information such as, "the room had a ceiling," since this very high schema-related information can be assumed for any room.

Overall, it is clear that schemas can operate to edit the information that is recalled. It may be that the editing procedure is sometimes used to edit out schema-unrelated information (in fact, if the demand characteristics for total recall are not too severe, one would think that a principle of least effort would tend to produce some editing of schema-unrelated information). However, the current experimental findings suggest schema-based editing serves to eliminate very high schema-related information, and thus this process operates in a direction opposed to the basic schema findings.

Functions of Schemas in Memory

Our analysis of the literature suggests that there is evidence for schemas operating in all five schema-based processes. Schemas have been shown to affect memory through attention processes, through acting as a framework to preserve episodic information, through integration of old and new knowledge, through a retrieval process, and through an output editing process. While the evidence is not completely clear, it would appear that the basic schema findings are due to a mixture of: schemas operating as a framework to preserve schema-related information; schemas operating to integrate old schema-based

information with new episodic information to give the appearance of increased memory for schema-based episodic information; and schemas operating in retrieval to facilitate the location of schema-related information. Currently the evidence does not suggest that schemas operating to direct attention or operating as output editors are major factors in the memory process.

Memory for Schema-Related and Schema-Unrelated Information

A number of researchers have pointed out that there appear to be some major inconsistencies in schema theory approaches to the issue of memory for schema-related and schema-unrelated information (e.g., Thorndyke & Yekovich, 1980). In this last section we would like to formulate the problem, and attempt to use the framework developed earlier to resolve some of the apparently conflicting data. The basic problem is that there are a number of studies that do not give the basic schema effects described earlier in the paper. Thus, some studies of script memory (Graesser, Gordon, & Sawyer, 1979; Graesser, Woll, Kowalski, & Smith, 1980) and some studies of picture memory (Friedman, 1979) find memory for schema-unrelated information to be better than memory for schema-related information.

Recall versus recognition. The first step in working out these problems is to distinguish the type of memory test involved. There is essentially total agreement that for recall tasks the basic schema effect is found: schema-related information is better recalled than schema-unrelated information.

In terms of our analysis this general finding is due to the powerful schema-based processes of integration and retrieval during recall.

However, for recognition memory the studies give apparently mixed results. Thus, some experiments with text found that recognition memory for schema-related information is better (Bower, Black, & Turner, 1979) while other experiments found that recognition for schema-related information is worse (Graesser, Gordon, & Sawyer, 1979; Graesser, Woll, Kowalski, & Smith, 1980). There is a similar divergence in results for studies using recognition memory and nonlinguistic materials. Some studies found that recognition memory for schema-related material is better (Brewer & Dupree, 1983; Goodman, 1980) while other studies find it to be worse (Friedman, 1979). Some of these difficulties can be resolved by taking into account the time interval for test, the types of "schema-unrelated" information used, and the relative contributions of episodic and generic information.

Delay of memory test. Within the set of studies on the schema-related/schema-unrelated issue there is a tendency for memory tasks that use relatively short time intervals to find schema-unrelated information to be equal or better than schema-related information (Brewer & Dupree, 1983; Friedman, 1979; Graesser, Gordon, & Sawyer, 1979), whereas memory tasks that involve a longer time interval tend to show schema-related information recognized better than schema-unrelated (Brewer &

Dupree, 1983; Goodman, 1980; Graesser, Woll, Kowalski, & Smith, 1980). Thus, it appears that part of the apparent conflict between these studies is due to good recognition for "surface" information after short time intervals and the loss of this information after longer time intervals, leading to an advantage for schema-based information. While this analysis accounts for much of the conflicting data, there still remains some theoretical and empirical disagreement about the strength of the episodic memory trace for schema-related and schema-unrelated information.

Relative contributions of episodic and generic information. In attempting to analyze the results of experiments in this area, one should also use the analysis of the different types of memory processes to distinguish the relative contribution of episodic and generic information in a particular experiment. Bower, Black, and Turner (1979) found that script-relevant items were better recalled than script-irrelevant items, whereas in direct contrast Graesser, Woll, Kowalski, and Smith (1980) arrived at the opposite conclusion. The difference between these studies is that Bower, Black, and Turner (1979) based their conclusion on the overall correct recall data, which included contributions of both episodic and generic information. On the other hand, Graesser, Woll, Kowalski, and Smith (1980) used the intrusion rate to estimate the amount of generic information. Then they subtracted this estimate from the overall correct recall to

obtain an estimate of the amount of episodic information. If one combines the data in the Graesser study for both episodic and generic contributions, the overall recall data are in good agreement with the Bower data. Thus, in attempting to compare studies in this area one must be careful to analyze the findings in terms of the relative contributions of episodic and generic information.

Type of schema-related and schema-unrelated information. A final factor to be considered is the nature of the schema-unrelated information in these studies. As discussed earlier, one must distinguish between schema-irrelevant information and schema-inconsistent information. For schema-irrelevant versus schema-relevant information it still seems to us that there is some conflict, both in theory and in data, that cannot be accounted for by our analysis. We clearly need more detailed experiments to determine what the strength of the memory trace is for these types of information in different domains. For schema-inconsistent information the issue seems simpler. Most theorists who have explicitly discussed this type of information have hypothesized that it will show high recognition and perhaps high recall. The usual line of reasoning is that much attention will be devoted to schema-inconsistent information, leading to a stronger memory trace, and also that possibly more effort will be devoted to attempting to force schema instantiation, thus giving rise to a more elaborated memory representation. There is some

experimental evidence to support these assumptions (Bower, Black, & Turner, 1979; Friedman, 1979).

Conclusion

We think that an understanding of how new knowledge interacts with old knowledge will play a major role in the development of a scientific theory of the human mind. In this paper we have attempted to show how schema theory has been formulated to deal with the relationships between old and new knowledge. We have argued that the rise of schema theory represents a continuation of a general trend in the study of the mind away from the assumptions of British Empiricism toward those of Continental philosophy. We have proposed that an understanding of the mind will require a number of very different types of schema theories and have pointed out the problems involved in relating the unconscious mental structures and processes of the schema to the phenomena of conscious experience. Finally, we have attempted to develop a more explicit account of the operations of schemas in the memory process and reanalyze the experimental literature in terms of this framework. Our analysis suggests that schema-based processes operate to: (a) direct attention, (b) serve as a framework to preserve episodic information, (c) combine generic information with episodic information to form instantiated schema memory representations, (d) act as a retrieval mechanism in recall, and (e) act as a mechanism to edit memory output.

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Table 1

A Classification of Major Research Paradigms in Terms of the

Contrast Between the Assumptions of British Empiricism and Continental Philosophy

	British Empiricism	Bartlett's Theory	Stimulus-Response	Information Processing	Modern Schema	Revised Schema	Continental Philosophy	
Atomistic	+	-	+	+	-	-	-	Molar
Parsimonious	+	+	+	+	+	-	-	Modular
Associationistic	+	-	+	-	-	-	-	Non Associationistic
Particularistic	+	-	+	-	-	-	-	Generic/Abstract
Passive	+	-	+	+-	-	-	-	Active
Mechanistic	+	-	+	+-	-	-	-	Purposive
Finite	+	-	+	-	-	-	-	Generative

Note. + indicates general acceptance of the British Empiricist assumptions.

- indicates general acceptance of the Continental assumptions.

+- indicates that some members took one position and some the other.

In order to make the contrast clear the description of British Empiricism is of a conservative version of that tradition.